(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification⁷: **C02F**

(21) International Application Number:
PCT/US2004/035960

(22) International Filing Date: 29 October 2004 (29.10.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/515,921   29 October 2003 (29.10.2003)   US
10/978,086   28 October 2004 (28.10.2004)   US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI,
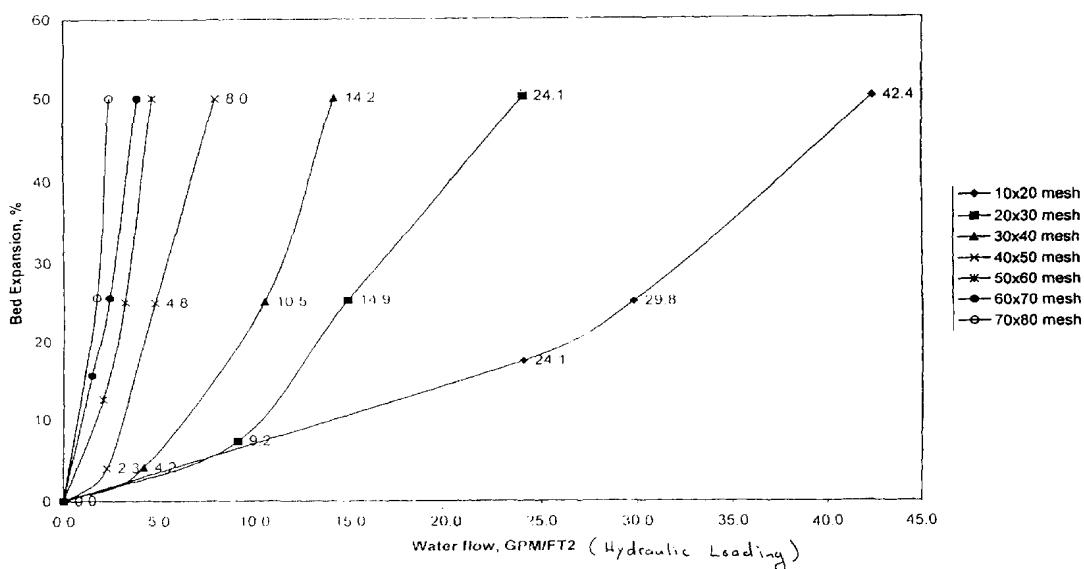
(54) Title: DYNAMIC UP-FLOW ZEOLITE SYSTEM

Bed Expansion Data on Individually Sieved Screen Fractions

(57) **Abstract:** Systems and methods are provided for the removal of a contaminate from an aqueous medium using a zeolite-based sorption column. The systems and methods include an optimized relationship between the hydraulic loading, zeolite mesh size, distribution of zeolite mesh sizes and zeolite bed volume expansion to provide a highly effective sorption column that resists clogging while increases capacity.

SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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Published:
— *without international search report and to be republished upon receipt of that report*

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DYNAMIC UP-FLOW ZEOLITE SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

The present PCT application is related to and claims priority to United States Provisional Application Serial Number 60/515,921, filed on October 29, 2003, entitled

5   DYNAMIC UP-FLOW ZEOLITE SYSTEM, and to a United States non-provisional patent application filed October 28, 2004, identified by Atty. Docket No. 33735/US/2, entitled DYNAMIC UP-FLOW ZEOLITE SYSTEM, both of which are incorporated herein in their entirety by reference.

FIELD OF THE INVENTION

10   The invention generally relates to methods and systems for removal of target contaminates from an aqueous media source. More specifically, the invention provides systems and methods for enhancing the effectiveness of a zeolite-based sorption column, both in increasing the capacity of zeolite in the system, and in minimizing the clogging of trapped particulates within the zeolite in a column or system.

15   ## BACKGROUND OF THE INVENTION

Cities and towns throughout the world depend on having clean potable water supplies. The dependence on clean water has increased as the population of the world has increased, especially as industrial use of rivers and lakes have become commonplace. The increased industrial use of fresh water supplies has resulted in a corresponding decrease in water quality

20   throughout the world, due principally to industrial related release of pollutants into the water supplies. The decrease in water quality is contravening to the world's increased dependence on clean potable water supplies, requiring a concerted effort toward both minimizing the release of pollution into the water supplies and removing existing pollution in water supplies throughout the world.

25   Conventionally, water treatment facilities are often equipped with specialized systems for removal of target pollutants from a water supply. For example, contacting the water supply with an affinity material having sorptive qualities toward the target pollutant of concern in the water source. Typically, these sorptive materials are constrained in a column that receives the water source, in a down-flow fashion, allowing the movement of the water

30   source and gravity to compact the sorptive material through-which the water source will flow. Although these down-flow systems tend to beneficially act as filters, due to the compacted sorptive material, they also tend to clog and rarely provide adequate space between each

sorptive material particle and the aqueous media source for maximal sorptive properties. These are a significant issue, *i.e.*, system capacity and system clogging, when a large volume of water is being treated, for example at a municipal water treatment facility.

In more limited settings, water supplies have been passed through sorptive columns in an up-flow manner. However, clogging and inadequate movement of the water source over the sorptive material have proven problematic.

Against this backdrop the present invention was developed.

BRIEF SUMMARY OF THE INVENTION

The present invention provides systems, methods and compositions for the removal of target contaminates from an aqueous medium. Such systems, methods and compositions are based on the sorptive capacity of zeolite, including modified zeolite, for removal of contaminates like radium, arsenic, uranium and chromium from aqueous media sources.

Embodiments of the present invention provide methods and systems for optimizing the contact time of aqueous media with relatively high surface area zeolite. For example, embodiments of the invention include design of systems, and the systems, for correlating the optimal up-flow hydraulic loading of an aqueous medium into a column for a particular zeolite mesh size at a target contact time. Optimal results combine hydraulic loading, range of zeolite mesh sizes, expansion percentage of the particular zeolite under the hydraulic loading conditions, and resultant contact time of the aqueous media with the expanded zeolite. Optimal parameters are used to fabricate a highly effective zeolite based sorption column that combines both high capacity and low clogging due to the highly mixed and thereby scoured zeolite particles.

Embodiments of the present invention also provide systems for the removal of contaminates from an aqueous medium. Typically, systems of the present invention contain zeolite having a mesh size of from about 10X20 to about 40X70, under expansion conditions that result in zeolite bed expansion of from about 25% to about 50%. Systems of the invention optimize zeolite capacity while reducing or minimizing particulate clogging within the zeolite as compared to conventional down-flow or up-flow arrangements of the zeolite. In particular, embodiments of the present invention reduce iron and other like precipitation within and through the column, *i.e.*, reduce the level of "red cloud" that occurs with respect to zeolite and modified zeolite.

These and various other features as well as advantages which characterize the invention will be apparent from a reading of the following detailed description and a review of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates bed expansion for individually "sieved screen" zeolite fractions under varying hydraulic loading parameters.

Figure 2 illustrates bed expansion for individually "sieved screen" zeolite fractions
5   under varying hydraulic loading parameters.

Figure 3 illustrates bed expansion for Rotap size zeolite composites under varying hydraulic loading parameters.

Figure 4 illustrates bed expansion for Rotap size composites under varying hydraulic loading parameters.

10   ## DETAILED DESCRIPTION OF THE INVENTION

Definitions:

The following definitions are provided to facilitate understanding of certain terms used frequently herein and are not meant to limit the scope of the present disclosure.

"Aqueous medium" refers to water or any liquid made with water as a constituent. In
15   some cases, aqueous medium or media comprises one or more contaminates. For example an aqueous medium containing Cr^{6+}, can be ground water supplies contaminated with Cr^{6+} where the ground water supply is obtained from the water table adjacent and/or in the vicinity of an automobile manufacturing plant. In other cases, the contaminate in an aqueous medium is arsenic uranium, radium or other materials from any number of sources. Note that aqueous
20   medium can include particulates, i.e., dirt, soil, precipitates, etc that lead to conventional filter clogging.

"Feed" refers to an aqueous medium before treatment with the systems, methods and/or compositions of the present invention, for example, a flowing water source before it enters a water treatment facility, or an underground water supply before it enters the systems
25   of the present invention.

"Maximum Contaminant Level" or "MCL" is the highest level of contamination for a particular contaminate that is allowed in drinking water in the United States, taking into account best treatment technology and cost. These standards are typically enforceable. Note that Maximum Contaminant Level standards are envisioned to encompass or correspond to
30   the same approximate standards in countries outside the United States, and in may cases are enforceable in those countries.

"Pollutant" or "contaminate" are used interchangeably and refer to a material within an aqueous medium having sorptive characteristics that are consistent with their removal by

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zeolite or a modified zeolite. Pollutants of the present invention include but are not limited to arsenic, radium, chromium and uranium. For example a modified zeolite, *e.g.*, ferrous form zeolite, removes chromium from an aqueous medium.

5 "Precipitate" refers to material that can conventionally clog a filter or sorption-based device during flow of an aqueous medium through the filter or sorption-based device. Exemplary precipitates include iron precipitates (forming what has been termed a "red cloud" in a discharged aqueous medium), other chemical precipitates, and various sized particulates.

"Zeolite" refers to a natural and/or synthetic zeolite. Natural zeolites are hydrated silicate of aluminum and either sodium or calcium or both, for example clinoptilolite and
10 chabazite. Synthetic zeolites are made by a number of well known processes, for example gel or clay processes, which form a matrix to which the zeolite is added. Example synthetic zeolites include Linde® AW-30 and Zeolon® 900. Note that a coarse zeolite has an average mesh size of about 12X40 or 10X40. Finer zeolite mesh sizes include, but are not limited to, 20X50, 40X70, and 50X80. Examples of particular zeolites for the removal of contaminates
15 are disclosed within US Patent Application Nos. 10/255364, filed 9/25/02, 10/256854, filed 9/26/02, and 10/256853, filed 9/26/02 which are each herein incorporated in there entirety by reference.

"Remove" refers to the detectable decrease of a target material, for example Cr^{6+} or other solutes or contaminates, from a source, for example ground water. Typically, removal
20 of a target material from an aqueous source is at least 50%, preferably at least 75% and most preferably at least 90%, from the original levels (feed levels) in the zeolite treated source. Typically, the concentration of the solute or contaminate in the aqueous medium is changed from a first level to a second lower level using the embodiments of the present invention.

"Absorb" and "adsorb" refer to the same basic principle of one substance being
25 retained by another substance. The processes can include attraction of one substance to the surface of another substance or the penetration of one substance into the inner structure of another substance. For example, the present invention contemplates that ferrous-form zeolite can either absorb and/or adsorb six-valent chromium out of an aqueous medium and that for purposes of the present invention, the two principles are interchangeable. Other terms used to
30 describe this interaction include sorption, binding or trapping, each of which is contemplated to be within the definition of absorption and/or adsorption.

Embodiments of the present invention provide methods, systems and compositions for removal of target contaminates from an aqueous medium, for example, removal of arsenic from a source of ground water. In general, the methods, systems and compositions of the
35 present invention rely upon zeolite or modified zeolite absorption columns, for example

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ferrous-form loaded zeolite columns. Embodiments of the present invention combine the sorptive characteristics of target zeolite with an unique up-flow, high retention time, system to maximize contact time between the aqueous medium and zeolite and to minimize or reduce potential for clogging of the zeolite during such contact time.

5   **Aqueous Media Hydraulic Loading, Zeolite Mesh Size, And Bed Expansion:**

The present invention provides zeolite-based adsorption and/or absorption columns (or other zeolite constraining device) for optimized hydraulic loading of an aqueous media, for a target zeolite mesh size that results in optimal zeolite expansion and aqueous media/zeolite contact time. Zeolite and modified zeolite containing columns provide well-
10   mixed zeolite having fewer contaminates within the zeolite, for example surface iron, to react with and form "red cloud" type precipitates for example.

With regard to the zeolite used in embodiments of the present invention, either natural or synthetic zeolilte can be used. Compositionally, zeolites are similar to clay minerals, where zeolites are natural hydrated silicate of aluminum and either sodium, calcium or a
15   mixture of both. However, unlike clays, which have a layered crystalline structure (similar to a deck of cards that is subject to shrinking and swelling as water is absorbed), zeolites have a rigid three-dimensional crystalline structure, for example a honeycomb-like crystalline structure. Zeolites' rigid honeycomb-like structure consists of a network of interconnected tunnels and cages, thereby forming a series of substantially uniformly sized pores. Aqueous
20   media moves freely in and out of the pores formed by the crystalline structure, making zeolite an excellent sieving or filtration type material, as well as providing a large surface area for interacting with target pollutants.

There are a number of natural zeolites useful in the context of the present invention, including, clinoptilolite, chabazite, phillipsite, mordenite, analcite, heulandite, stilbite,
25   thomosonite, brewsterite, wellsite, harmotome, leonhardite, eschellite, erionite, epidesmine, and the like. The natural zeolites of the present invention differ in density, cation selectivity, molecular pore size, and cation affinity. For example, clinoptilolite has 16% more void volume and pores, and is as much as 0.2 mm larger in average diameter than analcime, another common zeolite. Clinoptilolite is a preferred natural zeolite useful in the generation
30   of ferrous-form zeolite. In addition, natural zeolites that have been modified to have particle sizes from 10X20 mesh, 20X30 mesh, 30X40 mesh, 50X60 mesh, 60X70 mesh, 70X80 mesh, and preferably 40X70 mesh, and most preferably 50X80 mesh, are most useful in the present invention. Zeolite "fines" (powder) are typically removed before use in the present invention to prevent plugging in the tanks of the present invention.

Tables 1 and 2 provide a list of companies that presently produce zeolite minerals in either the United States or Canada. Table 1 provides a chemical analysis of the companies' zeolite materials, and Table 2 provides the physical properties of the corresponding zeolite materials. Tables 1 and 2 are provided as illustrative of the type of zeolite material that can
5   be used for large scale use in practicing the present invention.|

Table 1 – Chemical Analysis (Expressed in Weight %)

Company	Location	Na_2O	K_2O	CaO	MgO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3
Addwest Minerals	WY	4.7	1.9	1.6	0.65	74.0	14.0	0.1	2.1
American Research	NV/CA	3.5	3.8	0.7	0.4	69.1	11.9	---	0.74
Am. Absorbents	OR	0.8	3.8	0.7	0.4	69.1	11.9	0.2	0.7
Stellhead Res.	CA/NM/OR	0.8	3.8	0.7	0.4	69.1	11.9	0.2	0.4
Teague Minerals	OR	0.9	4.7	1.4	0.3	64.1	11.8	0.3	2.58
Zeotech	TX	0.6	1.7	2.4	0.7	68.4	12.1	NK	NK
St. Cloud Mining	NM	0.9	3.3	3.3	1.0	64.7	12.6	0.2	1.8
W-Way Zeolites	Canada	2.5	2.7	3.4	1.3	65.8	14.3	0.3	2.6
Highwood Res	Canada	2.78	2.79	3.78	0.95	64.5	13.7	0.27	2.19
C2C Mining	Canada	1.35	1.57	2.51	1.55	66.8	11.2	0.6	5.2

Table 2 – Physical Properties

Company	Ionic Exch Capacity (meq/g)	H_2O % Adsorption	Free Silica (%)	SG	Color	pH (natural)	Pore Diameter (Å)	Hardness
Addwest Minerals	2.00	14.0	2.00	1.5	pale blue		4.4	3.7

American Research	1.85	12.3	NK	NK			4.0	5.1
Am. Absorbents	1.4		1.50	2.3	white	8.0	4.0	3.8
Stellhead Res.	1.30		0.09	1.6	white	8.0	4.0	5.1
Teague Minerals	1.77		low	2.2	off white		not provided	not provided
Zeotech								
St. Cloud Mining	1.60		0.01<	2.3	white	8.0	4.0	3.8
W-Way Zeolites	1.00	25.0	NK	2.4	off white/pale green	8.1	6.5	NK
Highwood Res	1.00		10.0	2.0		7.0		
C2C Mining	NK	NK	5.00	2.3	brown	5.0?	NK	NK

Synthetic zeolites can also be used in the context of the present invention. Synthetic zeolites are made by well known processes, such as gel process (sodium silicate and alumina) or clay processes (kaolin), which form a matrix to which the zeolite is added. Preferable synthetic zeolites include Linde®AW-30, Linde®AW-500, Linde®4-A and Zeolon®900.

5   The systems and methods of the present invention can utilize either natural, synthetic or mixtures of natural and synthetic zeolite.

As discussed more fully below, finer mesh sizes of zeolite are preferable to coarser mesh sizes of zeolite within the context of the present invention, because finer zeolite mesh sizes facilitate proper bed expansion at lower hydraulic loading rates. Lower hydraulic

10   loading rates facilitate maximal contact times of the aqueous media with the zeolite, thereby maximizing the sorptive capacity of the zeolite. In addition, utilizing narrower size ranges of fine zeolite, as compared to broader, less-defined, ranges of zeolite, allows for the majority of the zeolite material to act consistently/predictably under hydraulic loading conditions for a particular column. Enhanced consistency and predictability facilitates design and efficiency

15   of systems of the present invention. Further, optimized parameters of the present invention provide well-mixed zeolite material thereby reducing or eliminating trapped precipitates

within the zeolite material and on the surfaces of the zeolite materials, for example, reduces the amount of red cloud formed from iron on the surface of the media.

In preferred embodiments, zeolite mesh sizes and ranges are provided that allow for hydraulic loading between 3-25 gallons per minute gpm/ft^2, and more preferably in the 4-15

5   gpm/ft^2, and most preferably in the 4-6 gpm/ft^2, that result in bed expansion of from about 25% to about 75% (from the settled volume to the zeolite volume under hydraulic loading), and preferably from about 25% to about 50%. Adequate column diameters are determined from the required capacity of the zeolite material, the hydraulic loading, the predicted expansion percentage, and the like. Note that in some instances the percent increase in bed

10   expansion can be greater than 50% - 75% as long as enough zeolite remains in the column to provide the capacity for removing target contaminates from the aqueous medium.

In more detail, experiments were performed to optimize hydraulic loading of an aqueous medium for a target zeolite mesh size that then provides preferred expansion percentage for that target zeolite mesh size. Target zeolite bed expansion is generally

15   between 25% to 50%, as is correlated from the field of affinity chromatography and other like arts. Note that this range is preferred, although smaller percent bed expansion and larger percent bed expansion can be used dependent on the end-use and efficiency that the end-user is needing. Figures 1 and 2 illustrate that a finer mesh size, for example 60X70, meets the bed expansion and hydraulic loading criteria for optimized pollutant removal from an

20   aqueous medium, i.e., provides adequate contact time for the aqueous medium on the zeolite or modified zeolite. Both Figures 1 and 2 show the bed expansions as a function of hydraulic loading for a number of different zeolite mesh sizes (note that coarsest size fractions are not included in Figure 2 to enhance the definition of the finer fractions). The graphs show that preferred bed expansion (25% to 50%) is achieved for finer mesh sizes utilizing lower

25   hydraulic loading, thereby allowing for longer retention times of the media on the zeolite. Note that the data graphed in Figures 1 and 2 can be used to design a column having any number of different zeolite mesh sizes as long as the appropriate hydraulic loading parameters are followed. Therefore, Figures 1 and 2 provide a relationship for determining how to maximize contact time of a medium on a particular zeolite mesh size and thereby

30   maximize the removal capacity for that zeolite mesh size.

Referring to Figures 3 and 4, composite zeolite materials were similarly tested to determine preferred hydraulic loading rates for particular zeolite composites that result in bed expansion. Note that composite materials were prepared by mixing equal weights of each included fraction, for example a 50X80 composite mesh includes 33% 50X60, 33% 60X70

35   and 33% 70X80. In particular, the 50X70 mesh composite showed identical flow at 50%

expansion, as did the 60X70 fraction although the curve profile is more curved. Composites with 50 and 60 mesh at the bottom size did not meet the fluidization criteria and required too much water.

5　　　　Finally, increasing the expansion of a finer zeolite media, for example by 40%, ensures that at least 40% of the material is fluidized and that the remaining zeolite is dynamically moving, *i.e.*, mixing against the other settled material in preparation to being fluidized itself, not sitting stagnant. This dynamic movement of zeolite ensures that few pockets of stagnant aqueous media or zeolite is present in the column thereby reducing clogging and formation of precipitates on the surface of the zeolite. In addition, dynamic

10　movement of zeolite facilitates the uniform interaction of zeolite with contaminates within the aqueous media.

　　　　Note also that although the preceding disclosure is directed toward removal of a solute or contaminate from an aqueous medium that is generally considered detrimental, for example arsenic or chromium, to the aqueous medium, other embodiments of the present

15　invention also include removal and isolation of potentially useful solutes from an aqueous medium, for example, metal extractions from a mine. Increased contact between the zeolite and useful solute, and thereby increased removal of useful solute from an aqueous medium, makes that removal process that much more profitable.

Systems And Methods For Removal of Pollutants From Aqueous Medium

20　　　　As discussed above (see Figures 1-4), a correlation between hydraulic loading rates, zeolite size, ranges of zeolite sizes, and retention times has been developed for designing a system and method for the removal of contaminates from an aqueous media. In a first step, a target hydraulic loading rate is determined for a particular aqueous media source. For example, a source having a high level of a particular pollutant (for example arsenic) might

25　require a lower hydraulic loading rate, i.e., in the 4-6 gpm/ft^2 range, to maximize the retention time of the aqueous media and the zeolite, or a particular source or site may require a particular dynamic loading due to parameters beyond the system designers control. Using the relationships shown in Figures 1-4, an appropriate mesh size is determined for the particular hydraulic loading rate that would allow for about 25% to about 50% bed expansion during

30　·the course of the run (entire contact time of the aqueous media and zeolite within the column). For example, 50X60 mesh would provide 30% bed expansion under 4 gpm/ft^2 hydraulic loading. Finally, a determination is made as to how wide a distribution of zeolite mesh sizes can be included in the target column to allow for the proper functioning of the column (this also helps minimize expense by loosening the size distribution of the resultant

zeolite). Note also that a narrow range of mesh sizes allows for lower hydraulic loading rates because the majority of the material should expand under the predictable force (as compared to a fine zeolite that includes coarse material, these will struggle to expand under a predictable fashion under the same hydraulic loading conditions).

5   One embodiment of a system for removing a contaminate from an aqueous medium using the methods and compositions of the present invention includes having an aqueous medium feed with a first level of contaminate, e.g., Cr^{6+} in a ground or surface water source. The system may include a contaminate detection device or sampling device for determining the first concentration of one or more solutes in the aqueous media feed. A storage tank can

10   optionally be present to store aqueous medium prior to treatment with the methods and systems of the present invention. The storage tank can include a float to sense the content within the storage tank. The aqueous media is fed from the supply or storage tank into a column feed pump or other like device to pull the medium from the storage tank and feed it into a sorption column in an upflow fashion. Up-flow parameters, i.e., hydraulic loading,

15   zeolite size and distribution, column diameters, and the like are determined as above (see Figures 1-4). Aqueous media flow through the column creates a 25 to 50% zeolite bed expansion as anticipated by the relationship discussed above.

        Note that filters can be incorporated within the system to facilitate the removal of particulates from the media, including filters between the pump and sorption column and at

20   the top end of the sorption column to minimize the amount of zeolite that escapes each column run during bed expansion. It is also noted that the sorption column can be connected to a number of sorption columns in the system. Each column composition dependent on the hydraulic loading, zeolite mesh size and distribution, and bed expansion as discussed above. It should be noted that the columns can be connected in series or in parallel, dependent on

25   column pressures and flows. A second contaminate detection device can be on the discharge side of the columns to measure the concentration of one or more solutes or contaminates in the eluant, referred to as a second solute or contaminate concentration level.

        Note that the systems of the present invention are generally designed to be incorporated into conventional water treatment systems, and preferably are designed to be

30   incorporated into theses systems as stand-alone units. Typically, the incorporation of the systems and methods of the present invention do not require that the existing system be re-designed, but rather, that the removal systems and methods be adapted to function before, during or after more conventional water treatment. Preferably, embodiments of the removal systems and methods of the present invention are added to existing water treatment facilities

35   as a first treatment step. Preferably, embodiments of the present invention remove an amount

of pollutant from a water source to meet the current MCL for that pollutant in the United States by the EPA. Note also that the systems of the present invention are portable and can be designed for transport in trucks or other movable platforms to contaminated sites, for example to a well located in a high Cr^{6+} contaminated ground water area.

5   The systems and methods of the present invention are adapted for use with existing water treatment plants as a "turn-key" or "bolt-on" process to remove pollutants from aqueous media. These facilities can be used to improve the quality of aqueous media in a number of applications, including drinking water, waste water, agricultural water and ground water. In the same manner, the systems and methods of the present invention can be

10   incorporated into new water treatment plant designs, again as "turn-key" or "bolt-on" process to the conventional water treatment facility, or integrated into the facility as designed by one of skill in the art.

       Of particular importance, zeolite-based removal systems of the present invention facilitate movement of precipitates (chemical or otherwise) through the zeolite, and typically

15   avoid clogging within the zeolite (due to the bed expansion for each zeolite mesh size and mixing of zeolite against itself). Further, since the zeolite is typically finer and in a dynamic state within the column, it tends to be scoured by other zeolite particles within the column and thereby less likely to harbor contaminants upon its own surface, as the contaminants are often mechanically broken off the zeolite surface.

20   Having generally described the invention, the same will be more readily understood by reference to the following examples, which are provided by way of illustration and are not intended as limiting.

<div align="center">EXAMPLES</div>

Example I: Zeolite Bed Expansion Under Varying Hydraulic Loading Parameters

25   Approximately ten pounds of Zeolite, mesh sizes 10X20, 20X30, 30X40, 50X60, 60X70 and 70X80, was dry screened (Rotaps). Each fraction was soaked for 12 to 16 hours in water to allow complete water absorption. Fluidization test were conducted in a 4 inch diameter column of WRT design which includes one bubble cap assembly. The cap was shaved so that the gap around the circumference was even and would not enhance preferential

30   flow, channeling up the column.

       The effect of the gap was investigated using the 10X20 mesh zeolite. Gap widths between 0.187 and 0.257 inches were tested and the flow pattern was observed for each. For this size fraction, the gap seemed to make little or no defference within the limits tested. The flow from under the cap channeled in only one location regardless of the gap. The water

channel location was stationary and rose to a height of about 16 to 18 inches before a general diffusion was seen. At the column base zeolite was moving upward in the high-velocity channel and downward for the remainder of the area.

For the <20 mesh fractions, high velocity channeling was still observed but the flow
5   moved at random around the bubble cap. Cap gaps and the calculated average flow from under the cap were included on the data sheets for this series. The gaps were narrowed for the finer size fractions.

Referring to Figures 1 and 2 , bed expansions as a function of flow rate per foot squared is shown. The coarsest size fractions are not included in Figure 2 to enhance
10   definition of the finer fractions. The 60X70 mesh fraction most closely met the criteria for 50% bed expansion at 4 gpm/ft2. Note that the 70X80 mesh may have been to fine under the conditions of this example. For each test three points were recorded: 1) the minimum flow for general bed movement, 2) the flow for 25% bed expansion, and 3) the flow fro 50% bed expansion. Zero bed expansion was measured by natural settling of the zeolite after a brief
15   elutriation of the column.

Tables 3-9 provide specific numerical readings for the data shown in Figures 1 and 2. Note the minimum flow rate to obtain 25% bed expansion is shown in the tables.

Table 3: Fluidization Test For 10X20 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
24.5	0	0	0	0	0
28.75	17.3	2.1	24.1	0.257	3.7 (min flow)
30.6	24.9	2.6	29.8	0.257	4.5
36.75	50	3.7	42.4	0.257	6.5
Column Diameter – 4 in; column area – 0.0874 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					

Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. Given the coarse sample, the water channeled to one area of the column. Experimentation with the bubble cap width showed little difference in results (gaps were tried between 0.187 and 0.257 inches).

Table 4: Fluidization Test For 20X30 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
27.25	0	0	0	0.257	
29.25	7.3	0.8	9.2	0.257	1.4 (min flow)
34.1	25.1	1.3	14.9	0.257	2.3
40.9	50.1	2.1	24.1	0.257	3.7

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.

Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random.

Table 5: Fluidization Test For 30X40 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
27	0	0	0	0.189	0
28.12	4.1	0.37	4.2	0.189	0.88
33.75	25	0.92	10.5	0.189	2.2
40.5	50	1.24	14.2	0.189	2.9

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random.					

Table 6: Fluidization Test For 40X50 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
30.75	0	O	0	0.189	0
32	4.1	0.2	2.3	0.189	0.47 (min flow)
38.4	24.9	0.42	4.8	0.189	0.99
46.1	49.9	0.7	8	0.189	1.66
Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random.					

Table 7: Fluidization Test For 50X60 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
32	0	0	0	0.075	0

36	12.5	0.18	2.1	0.075	1.08 (min flow)
40	25	0.28	3.2	0.075	1.2
48	50	0.41	4.7	o.075	2.45

Column Diameter – 4 in; column area – 0.0873 ft²; Water disperser – Water Remediation Technology bubble cap, even gap.
Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random.

Table 8: Fluidization Test For 60X70 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (Inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft²		ft/sec
22.5	0	0	0	0.075	0
26	15.6	0.13	1.5	0.075	0.78 (min flow)
28.25	25.6	0.21	2.4	0.075	1.61
33.75	50	0.34	3.9	0.075	2.03

Column Diameter – 4 in; column area – 0.0873 ft²; Water disperser – Water Remediation Technology bubble cap, even gap.
Column was maintained in a true vertical position and the water was dispersed through a bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random.

Table 9: Fluidization Test For 70X80 mesh, rotapped

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
22.5	0	0	0	0.075	0
28.25	25.6	0.15	1.7	0.075	0.90 (min flow)
33.75	50	0.21	2.4	0.075	1.26
Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column was maintained in a true vertical position and water was dispersed through bubble cap with even gap around circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random. Minimum flow was at 25% expansion.					

Several zeolite composites were assembled to establish fluidization curves for each:
50X80 (equal weights of included fractions), 50X70 (equal weights of included fractions),
20X50 (equal weights of included fractions), 30X60 (equal weights of included fractions),
40X70 (equal weights of included fractions), and 30X70 (equal weights of included
fractions). Figures 3 and 4 display the fluidization curves for each composite. The 50X70
mesh composite showed the identical flow at 50% expansion as did the 60X70 mesh fraction
although the curve profile is more curved. Tables 10-16 provide specific numerical readings
for the data shown in Figures 3 and 4. Note the minimum flow rate to obtain 25% bed
expansion.

Table 10: Fluidization Test For 50X80 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (Inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
26.25	0	0	0	0.075	0

28.75	9.5	0.14	1.6	0.075	0.84 (min flow)
32.75	24.8	0.21	2.4	0.075	1.26
39.5	50.5	0.3	3.4	0.075	1.79

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.

Column was maintained in a true vertical position and the water dispersed through bubble cap with even gap around the circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random. Minimum flow was at 25% expansion.

Table 11: Fluidization Test For 50X70 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate	.	Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
26.125	0	0	0	0.075	0
27.6	5.3	0.1	1.1	0.075	0.6 (min flow)
32.5	24.4	0.26	3	0.075	1.55
39.25	50.2	0.34	3.9	0.075	2.03

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.

Column was maintained in a true vertical position and the water was dispersed through bubble cap with even gap around the circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random. Minimum flow was at 25% expansion.

Table 12: Fluidization Test For 20X50 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (Inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
23.5	0	0	0	0.125	0
25.125	6	0.32	3.7	0.125	1.15 (min flow)
29.25	24.5	0.65	7.4	0.125	2.34
35.25	50	1.14	13.1	0.125	4.11
Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column maintained in a true vertical position and water dispersed through the bubble cap with even gap around the circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random. Minimum flow was at 25% expansion.					

Table 13: Fluidization Test For 30X60 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
24.5	0	0	0	0.125	0
25.5	4.1	0.18	2.1	0.125	0.65 (min flow)
30.5	24.5	0.42	4.8	0.125	1.151
36.75	50	0.7	8	0.125	2.52
Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					

Column maintained in a true vertical position and water dispersed through bubble cap with even gap around the circumference. The water flow around the bubble cap appeared more random and the upflow channeling at the base of the zeolite bed moved at random. Minimum flow was at 25% expansion.

Table 14: Fluidization Test For 40X70 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft$_2$		ft/sec
24.5	0	0	0	0.125	0
25.0	2	0.11	1.3	0.125	0.40 (min flow)
30.5	24.5	0.29	3.3	0.125	1.05
36.75	50	0.42	4.8	0.125	1.51

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.

Column was maintained in a true vertical position and the water dispersed through the bubble cap with even gap around the circumference. The water flow around the bubble cap appeared more random and the upflow channel at the base of the zeolite bed moved at random.

Table 15: Fluidization Test For 30X70 mesh, comp. from Rotab Fractions

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
23.5	0	0	0	0.125	0
25.5	8.5	0.11	1.3	0.125	0.4 (min flow)
29.25	24.5	0.36	4.1	0.125	1.30
35.25	50	0.53	6.1	0.125	1.91

Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column maintained in a true vertical position and water dispersed through bubble cap with even gap around the circumference. The water flow around the bubble cap appeared random and the upflow channeling at the base of the zeolite bed moved at random					

Table 16: Fluidization Test For 40X70 mesh, pilot plant product

Bed Height (inches)	Expansion %	Flow Rate		Cap Gap (inches)	Average Flow Velocity Under Cap
		GPM	GPM/ft^2		ft/sec
24.25	0	0	0	0.125	0
25.5	5.2	0.08	0.9	0.125	0.29
30.3	24.9	0.2	2.3	0.125	0.72
36.38	50	0.38	4.4	0.125	1.37
Column Diameter – 4 in; column area – 0.0873 ft^2; Water disperser – Water Remediation Technology bubble cap, even gap.					
Column maintained in a true vertical position and water dispersed through bubble cap with even gap around the circumference. The water flow around the bubble cap appeared random and the upflow channeling at the base of the zeolite bed moved at random.					

Data from these Figures and Tables provided that a 50X70 mesh composite product having a bed expansion of 50% under 4.4 gpm/ft2 of water worked well.

In conclusion, the 60X70 mesh and 50X70 mesh composite appear to be the size zeolite particles that meet the bed expansion and hydraulic loading criteria of the present invention. It is worth noting that the finer particle curves show that finer material is extremely sensitive to flow rate. A small increase or decrease in flow will result in a substantial bed-height change.

Example 2: Up-flow 20X50 Mesh Zeolite Performs Well In Radium Removal From an Aqueous Source

Two Radium removal tests were independently performed using 20X50 mesh size composite zeolite, under up-flow conditions, using the relationships described in Figure 4.

Four 48 inch high columns having 4 inch diameters were connected in series, each column having approximately 10 pounds of 20X50 mesh zeolite per column. A series of pumps moves the source aqueous medium in an up-flow direction to "fluidize" the bed of each column (to a bed expansion within the 25 to 50% range).

Minimum bed expansion was attained with 0.23 cu ft of source flowing into each column. Referring to Tables 17 and 18, it is noted that radium levels were vastly diminished from each of the two sources: for the first source, 98,961 gallons of medium (Table 17) and for the second source, at least 59,531 gallons (Table 18). This data provides strong evidence that the present invention is useful for removing/reducing the levels of contaminates under high flow through situations.

Table 17: Elbum, Illinois Pilot Plant Study

Ra-226				Concentration (pCi/L)				
Date	Totalizer	Flow	MCL	Feed	C1	C2	C3	C4
4/22	0	0	5	12.1	--	--	--	--
4/24	2210	0.767	5	12.7	0.5	0.12	0.05	0.09
4/26	4688	0.860	5	14.1	0.42			0.31
4/30	8661	0.690	5	11.2	0.23	0.18	0.18	0.07
5/7	17108	0.838	5	20.1	2.19	0.36	0.1	0.12
5/16	27394	0.794	5	10.4	7.33	0.97	0.16	0.49
5/19	30699	0.765	5	13.8	5.66	0.82	0.15	0.12
6/9	--	--	5	2.03	7.29	2.46	0.27	0.08
7/10	76892	--	5	7.39	5.69	3.51	0.71	0.28
7/27	98961	--	5	13	10.4	5.7	2.84	1.56
8/19	103193	0.128	5	9.68	8.81	5.32	3.99	1.89
9/17	--	--	5	12.3	10.4	7.87	4.92	3.67
Ra-228				Concentration (pCi/L)				
Date	Totalizer	Flow	MCL	Feed	C1	C2	C3	C4
4/22	0	--	5	6.04	--	--	--	--

4/24	2210	0.767	5	8.62	0.51	0.33	0.6	0.18
4/26	4688	0.860	5	8.09	0.27	--	0.33	0.14
4/30	8661	0.690	5	6.68	0.98	0.21	0.22	--
5/7	17108	0.838	5	6.99	1.96	0.55	0.3	0.05
5/16	27394	0.794	5	3.89	1.68	0.4	0.27	0.33
5/19	30699	0.765	5	4.37	0.76	0.52	0.45	0.87
6/9	--	--	5	3.29	2.12	0.56	0.19	0.19
7/10	76892	--	5	13.5	10.2	4.49	2.14	0.96
7/27	98961	--	5	10.8	4.81	4.04	2.02	1.45
8/19	103193	0.128	5	7.29	7.25	4.01	4.75	5.54
9/17	--	--	5	8.75	10.1	10.4	5.57	3.99

Ra Combined				Concentration (pCi/L)				
Date	Totalizer	Flow	MCL	Feed	C1	C2	C3	C4
4/22	0	--	5	18.14	--	--	--	--
4/24	2210	0.767	5	21.32	1.01	0.45	0.65	0.27
4/26	4688	0.860	5	22.19	0.69	0	0.33	0.45
4/30	8661	0.690	5	17.88	1.21	0.39	0.4	0.07
5/7	17108	0.838	5	27.09	4.15	0.91	0.4	0.17
5/16	27394	0.794	5	14.29	9.01	1.37	0.43	0.82
5/19	30699	0.765	5	18.17	6.42	1.34	0.6	0.99
6/9	--	--	5	5.32	9.41	3.02	0.46	0.27
7/10	76892	--	5	20.89	15.89	8	2.85	1.24
7/27	98961	--	5	23.8	15.21	9.74	4.86	3.01
8/19	103193	0.128	5	16.97	16.06	9.33	8.74	7.43
9/17	--	--	5	21.05	20.5	18.2	10.49	7.66

Ra Combined				Cumulative Loading (pCi/g)				
Date	Totalizer	Flow	MCL		C1	C2	C3	C4

Date	Totalizer	Flow	MCL					
4/22	0	--	5		37.37			
4/24	2210	0.767	5		81.73			
4/26	4688	0.860	5		136.87			
4/30	8661	0.690	5		298.21			
5/7	17108	0.838	5		343.43	22.79	3.59	1.62
5/16	27394	0.794	5		375.76	88.22	11.64	
5/19	30699	0.765	5			102.2	13.67	
6/9	--	--	5					
7/10	76892	--	5					
7/27	98961	--	5					
8/19	103193	0.128	5		3.21	23.71	2.08	4.62
9/17	--	--	5		-44.05	-167.88	-666.37	-238.53

Ra Combined				Recovery (%)				
Date	Totalizer	Flow	MCL	Total	C1	C2	C3	C4
4/22	0	--	5	98.7	95.3	55.4		58.5
4/24	2210	0.767	5	98	96.9			
4/26	4688	0.860	5	99.6	93.2	67.8		82.5
4/30	8661	0.690	5	99.4	84.7	78.1	56	57.5
5/7	17108	0.838	5	94.3	36.9	84.8	68.6	
5/16	27394	0.794	5	94.6	64.7	79.1	55.2	
5/19	30699	0.765	5					
6/9	--	--	5					
7/10	76892	--	5					
7/27	98961	--	5					
8/19	103193	0.128	5	56.2	5.4	41.9	6.3	15
9/17	--	--	5	63.6	2.6	10.9	42.6	27

Table 18: Reddick, Illinois Pilot Plant Study

Ra-226				Concentration (pCi/L)		
Date	Total	Flow	MCL	Feed	C1	C2
5/20	0		5			
5/27	5855	0.581	5	2.98	0.02	0.06
6/2	10704	0.561	5	3.7	0.15	0.04
6/9	17007	0.625	5	1.36	2.35	0.10
6/12	21150	0.959	5	7.44	0.83	0.54
6/16	26768	0.975	5	16.40	2.11	1.09
6/19	30942	0.966	5	4.53	0.59	0.09
7/10	46889	0.527	5	2.96	0.54	0.09
8/14	59531	0.251	5	4.32	1.00	0.11
9/9		-1.590	5	4.09	1.02	0.61
9/27			5	3.22	1.56	0.83
Ra-228				Concentration (pCi/L)		
Date	Total	Flow	MCL	Feed	C1	C2
5/20	0		5			
5/27	5855	0.581	5	2.88	0.33	0.41
6/2	10704	0.561	5	3.00	0.13	0.44
6/9	17007	0.625	5	1.04	0.45	0.08
6/12	21150	0.959	5	1.46	0.21	0.23
6/16	26768	0.975	5	5.07	0.42	0.29
6/19	30942	0.966	5	4.79	0.07	0.53
7/10	46889	0.527	5	5.68	1.77	1.36
8/14	59531	0.251	5	3.38	1.57	0.47
9/9		-1.590	5	3.80	3.57	81
9/27			5	3.86	3.18	2.64

Ra Combined				Concentration (pCi/L)		
Date	Total	Flow	MCL	Feed	C1	C2
5/20	0		5			
5/27	5855	0.581	5	5.86	.35	.47
6/2	10704	0.561	5	6.71	.28	.48
6/9	17007	0.625	5	2.40	2.80	.18
6/12	21150	0.959	5	8.90	1.04	.77
6/16	26768	0.975	5	21.47	2.53	1.38
6/19	30942	0.966	5	9.32	.66	.62
7/10	46889	0.527	5	8.64	2.31	1.45
8/14	59531	0.251	5	7.70	2.57	.58
9/9		-1.590	5	7.89	4.59	1.42
9/27			5	7.08	4.74	3.47

Ra Combined				Cumulative Loading (pCi/G		
Date	Total	Flow	MCL	Feed	C1	C2
5/20	0		5			
5/27	5855	0.581	5		26.86	
6/2	10704	0.561	5		52.82	
6/9	17007	0.625	5		50.72	13.75
6/12	21150	0.959	5		77.83	14.68
6/16	26768	0.975	5		166.43	20.06
6/19	30942	0.966	5		196.52	20.20
7/10	46889	0.527	5		280.57	31.62
8/14	59531	0.251	5		334.57	52.56
9/9		-1.590	5		171.00	-104.56
9/27			5		171.00	-104.56

Ra Combined				Recovery (%)		
Date	Total	Flow	MCL	Feed	C1	C2
5/20	0		5			
5/27	5855	0.581	5	92.0	94.0	-34.3
6/2	10704	0.561	5	92.8	95.8	-71.4
6/9	17007	0.625	5	92.5	-16.7	93.6
6/12	21150	0.959	5	91.3	88.3	26.0
6/16	26768	0.975	5	93.6	88.2	45.5
6/19	30942	0.966	5	93.3	92.9	6.1
7/10	46889	0.527	5	83.2	73.3	37.2
8/14	59531	0.251	5	92.5	66.6	77.4
9/9		-1.590	5	82.0	41.8	69.1
9/27			5	51.0	33.1	26.8

Example 3: Up-flow 20X40 Mesh Zeolite Resulted In Lower Levels of Red Cloud Than Up-flow Through 12X40 Mesh Zeolite

Aqueous media from the same source was passed through either a 12X40 mesh zeolite or a 20X40 mesh zeolite at varying flow-rates. Discharge media was observed for
5   particulates, and in particular for "red cloud" formation. The smaller sized zeolite, 20X40, showed greater bed expansion at each flow rate and also more mixing at each flow rate. Several independent observations concluded that the medium that flowed over the 20X40 zeolite mesh had less red cloud formation than the medium that flowed over the 12X40 zeolite mesh. It appears that the increased bed expansion and mixing (scouring) reduced the
10   levels of iron on the 20X40 mesh to reduce the formation of the "red cloud."

It will be clear that the invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been described for purposes of disclosure, various changes and modifications may be made which will readily suggest themselves to those skilled in the art and which are encompassed
15   in the spirit of the invention disclosed herein and as defined in the appended claims.

WHAT IS CLAIMED IS:

1.   A method for removing a contaminate from an aqueous medium, the aqueous medium having a first concentration of contaminate, the method comprising:

determining a target hydraulic loading for the aqueous medium based on an anticipated contact time of the aqueous medium with a zeolite material;

determining the mesh size and size distribution of the zeolite material from the determined hydraulic loading that will provide about 25% to about 50% expansion of the zeolite bed volume when the aqueous medium is contacted with the bed volume in an up-flow direction;

providing the determined mesh size and size distribution of zeolite to the appropriate bed volume in a device for performing the up-flow contact; and

contacting the aqueous medium with the zeolite material at the target hydraulic loading wherein the contacting removes the contaminate from the aqueous medium from the first concentration to a lower second concentration.

2.   The method of claim 1 wherein the hydraulic loading for the aqueous medium is from about 3 gallons per minute/ft^2 to about 25 gallons per minute/ft^2.

3.   The method of claim 1 wherein the hydraulic loading for the aqueous medium is from about 4 gallons per minute/ft^2 to about 6 gallons per minute/ft^2.

4.   The method of claim 2 wherein the determined mesh size is about 60x70.

5.   The method of claim 2 wherein the determined mesh size is a composite mesh of 50x80.

6.   A system comprising:

at least one column comprising zeolite having a pre-determined mesh size ;

wherein the at least one column is adapted to receive, in an up-flow direction, an aqueous medium at a hydraulic flow such that about 25% to about 50% of the zeolite is expanded.

7.   The system of claim 6 wherein the predetermined mesh size is 40x70.

8.   The system of claim 6 wherein the predetermined mesh size is 50x80.

9.   The system of claim 6 wherein the predetermined mesh size is 60x70.

10.   The system of claim 6 further comprising a second column comprising zeolite having a predetermined mesh size wherein the second column receives the aqueous medium from the first column in an up-flow direction at a hydraulic flow such that about 25% to about 50% of the zeolite in the second column is expanded.

11. The system of claim 6 wherein the aqueous medium is loaded into the at least first column at 4 to 6 gallons per minute/ft^2.

12. A column adapted for receiving hydraulic loading of an aqueous medium of from between 3 and 25 gallons per minute/ft^2 and a bed volume of zeolite with a predetermined

5   mesh size, which upon application of the hydraulic loading in an up-flow direction results in 25% to 50% expansion of the zeolite bed volume.

13. The column of claim 12 wherein the zeolite mesh size is an composite of 40x70.

14. The column of claim 12 wherein the hydraulic loading is from about 4 to about 6 gallons per minute/ft^2.

10   15. The column of claim 12 wherein the zeolite mesh size is a fine mesh size of 60x70.

16. The column of claim 12 wherein the zeolite mesh size is a fine mesh size of 50x80.

17. The column of claim 12 further comprising a filter at one end of the column to prevent the zeolite from exiting the column when receiving the aqueous medium.

Figure 1
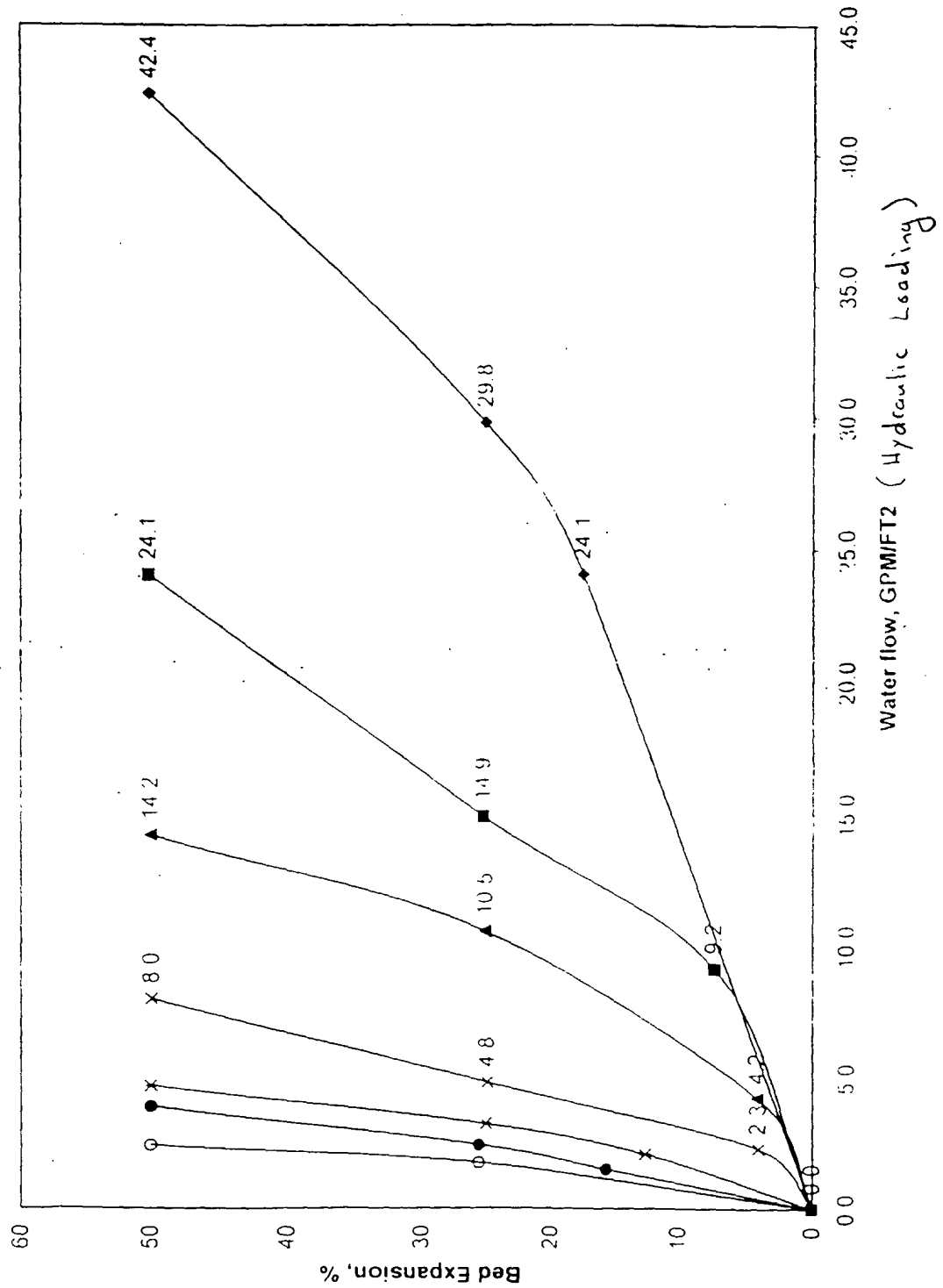Bed Expansion Data on Individually Sieved Screen Fractions

Figure 2
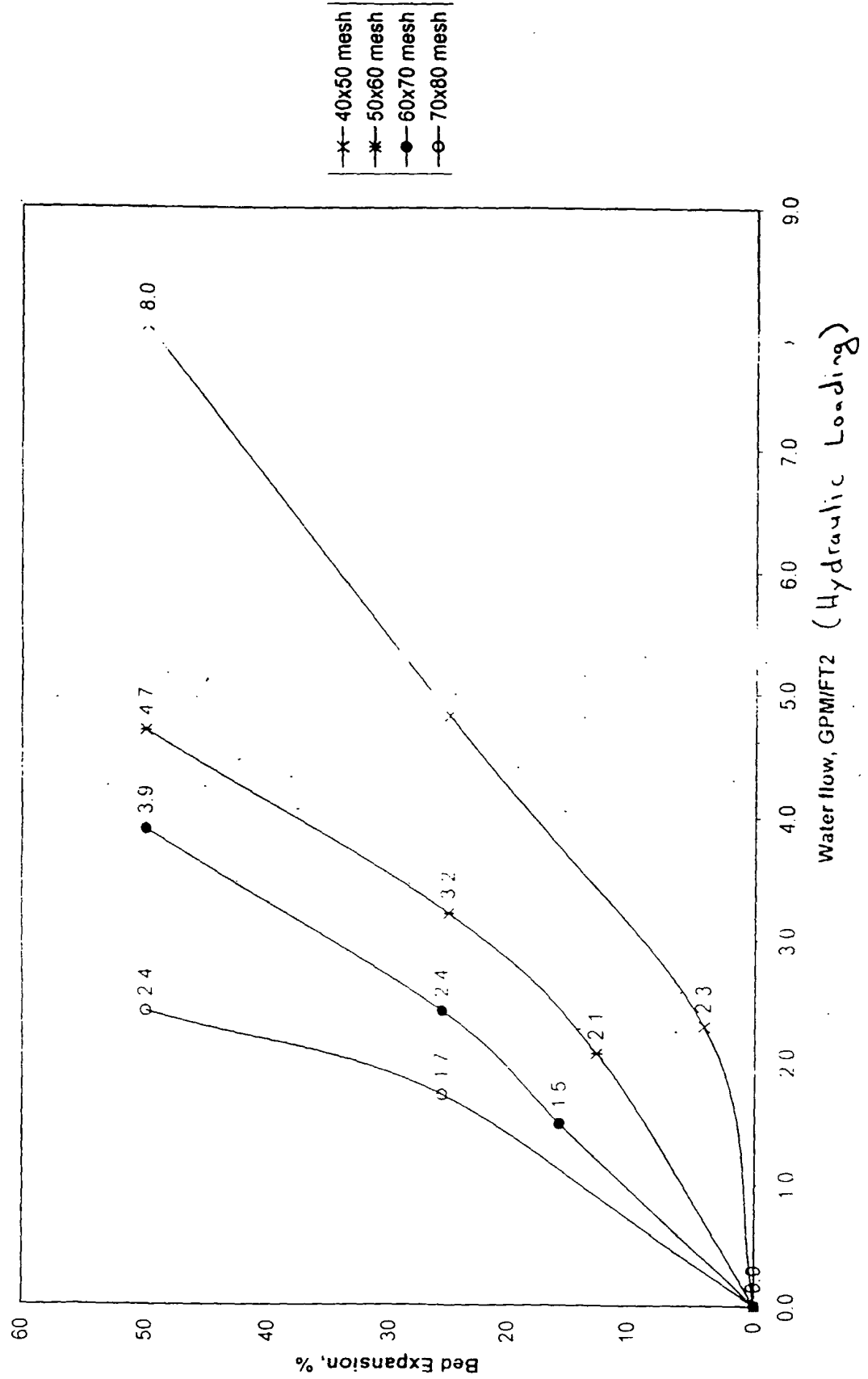Bed Expansion Data on Individually Sieved Screen Fractions
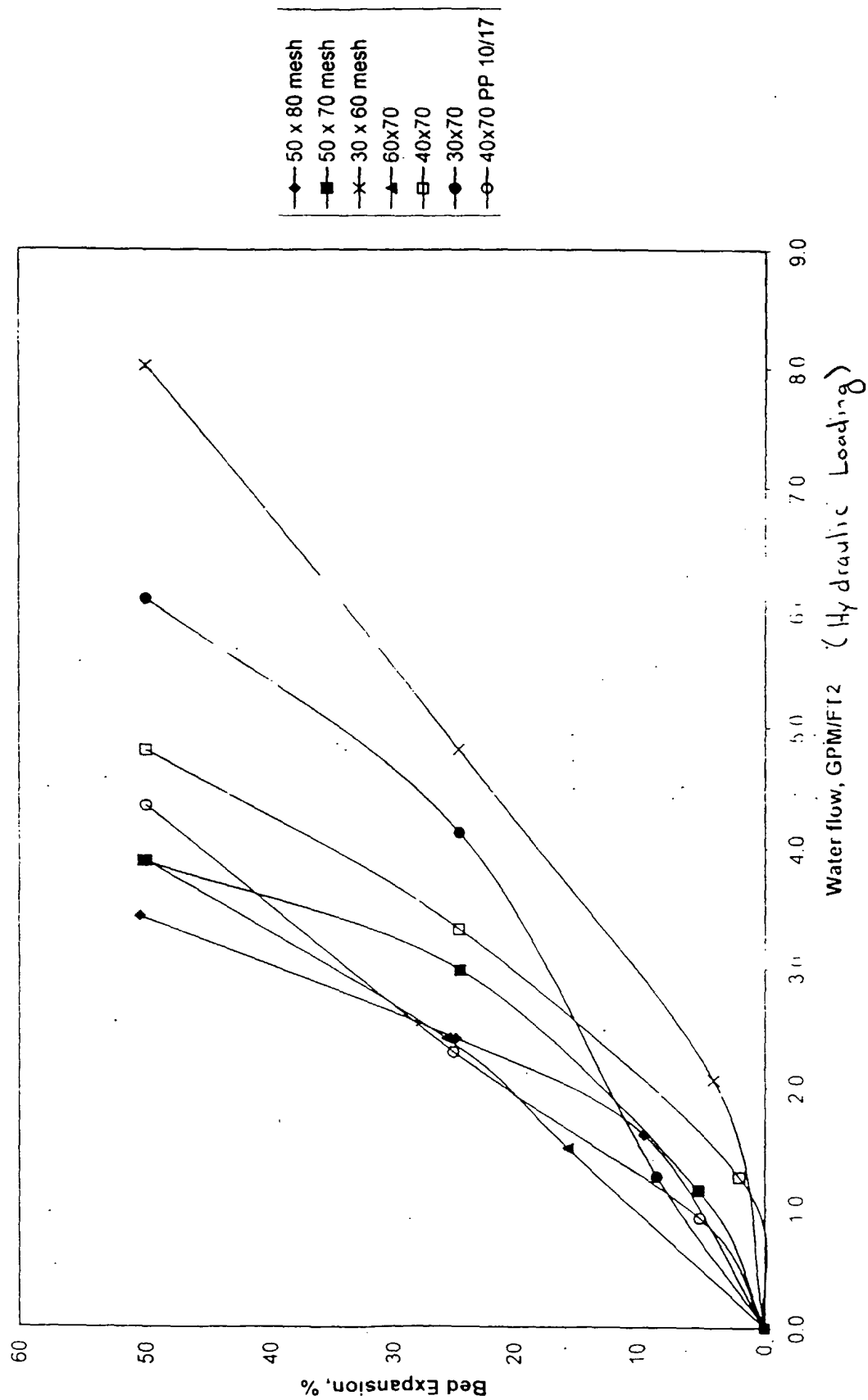
Figure 3
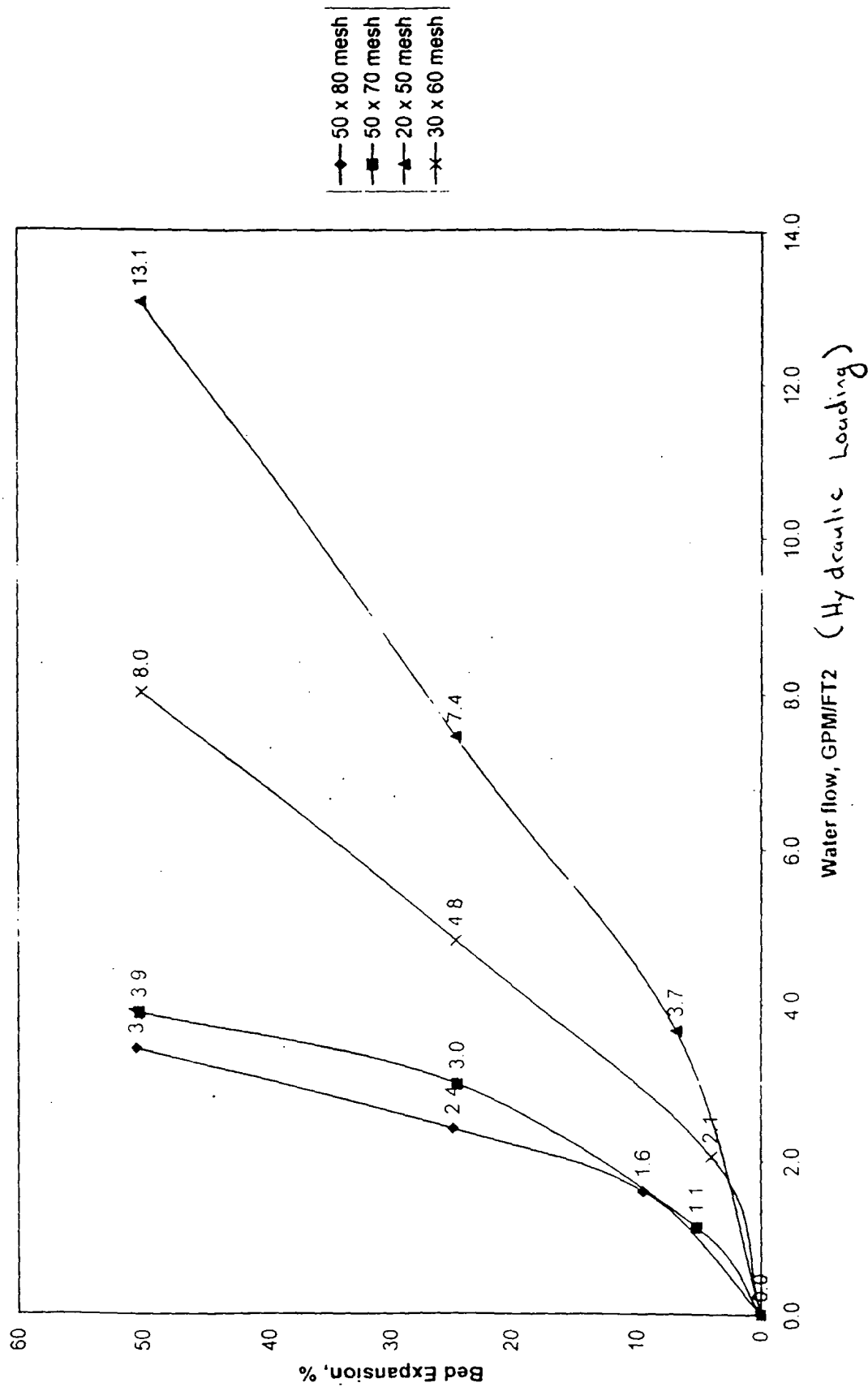Bed Expansion Data on Rotap Size Composites

Figure 4
Bed Expansion Data on Rotap Sieve Composites

PUB-NO: WO2005042407A2

DOCUMENT-IDENTIFIER: WO 2005042407 A2

TITLE: DYNAMIC UP-FLOW ZEOLITE SYSTEM

PUBN-DATE: May 12, 2005

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APPL-NO: US2004035960

APPL-DATE: October 29, 2004

PRIORITY-DATA: US51592103P (October 29, 2003) , US97808604A (October 28, 2004)

INT-CL (IPC): C02F00/

ABSTRACT:

CHG DATE=20050524 STATUS=O>Systems and methods are provided for the removal of a contaminate from an aqueous medium using a zeolite-based sorption column. The systems and methods include an optimized relationship between the hydraulic loading, zeolite mesh size, distribution of zeolite mesh sizes and zeolite bed volume expansion to provide a highly effective sorption column that resists clogging while increases capacity.